

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
14 October 2004 (14.10.2004)

PCT

(10) International Publication Number
WO 2004/086958 A1

(51) International Patent Classification⁷: A61B 1/00

(21) International Application Number:
PCT/US2004/009471

(22) International Filing Date: 29 March 2004 (29.03.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/406,336 3 April 2003 (03.04.2003) US

KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



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(54) Title: MAGNETICALLY PROPELLED CAPSULE ENDOSCOPY

(57) Abstract: Magnetically propelled capsule endoscopy provides for the medical examination of the gastrointestinal tract, reproductive tract, trachea/lungs, vascular system or any accessible body cavity. The capsule will be steered throughout the system by an external magnetic field. This instrument will provide for various real time imaging modalities, for physical property measurements and for tissue biopsy/excision. This instrument allows any appropriate system (i.e. non medical) to undergo analysis.

TITLE OF INVENTION

Magnetically Propelled Capsule Endoscopy

CROSS-REFERENCE TO RELATED APPLICATIONS

Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

REFERENCE TO SEQUENCE LISTING, A TABLE, OR A COMPUTER PROGRAM LISTING COMPACT DISC APPENDIX

Not Applicable

BACKGROUND OF THE INVENTION

This patent application may be applied to the field of medical imaging, tissue biopsy/excision and system imaging (i.e. non medical).

The digestive tract may be examined by the upper gastrointestinal endoscope, the lower gastrointestinal endoscope and the capsule endoscope. The upper gastrointestinal endoscope and the lower gastrointestinal endoscope require an anesthetic and are limited by the inability to examine the small intestine. The capsule endoscope does not permit real time imaging and precludes tissue biopsy/excision. All three methods provide a limited range of viewing/access angles.

BRIEF SUMMARY OF THE INVENTION

Magnetically propelled capsule endoscopy provides for the medical examination of the gastrointestinal tract, reproductive tract, trachea/lungs, vascular system or any accessible body cavity. The capsule will be steered throughout the system by an external magnetic field. This instrument will provide for various real time imaging modalities, for physical property measurements and for tissue biopsy/excision. This instrument allows any appropriate system (i.e. non medical) to undergo analysis.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Not Applicable

DETAILED DESCRIPTION OF THE INVENTION

This instrument may be used for the purpose of performing a medical examination of the digestive tract, reproductive tract, trachea/lungs, vascular system or any accessible body cavity. Other non medical systems may be effectively analyzed by the instrument. A capsule will be inserted into the appropriate location. Contained within the capsule may be the following basic components:

(#1 possibility) - magnets or magnetizable materials for movement and direction control; magnetic sensors; light sources; imaging lenses; transmitter and receiver for communication; magnetic pickup for power generation; gyroscope/accelerometer for location information; mechanical equipment for tissue biopsy/excision or other procedures; power source; electronics;

(#2 possibility) - magnets or magnetizable materials for movement and direction control; magnetic sensors; light sources, imaging lenses, power lines, communication lines, injection hoses, suction hoses and other lines/hoses extending out the back of the capsule and connecting to the external control device; gyroscope/accelerometer for location information; mechanical equipment for tissue biopsy/excision or other procedures; power source; electronics.

The choice of no physical connection (#1 possibility) or physical connection (#2 possibility), capsule size and capabilities will vary depending on the design/application. Many other components as described below may be designed into these two basic configurations.

The magnets or magnetizable material contained within the capsule will be bathed in an external magnetic field. The external magnetic field is created by any number of field generating structures with the arbitrary positioning of each structure. The number and configuration of the structures will depend on the design parameters. For explanation purposes, one structure will be centrally located on each face of an imaginary cube. Current will run through each of the six structures which essentially allows oppositely positioned pairs of structures to control each spatial dimension. The configuration of the instrument will be such that the patient's body passes through diagonally opposite edges of the imaginary cube. The capsule will be moved by appropriately changing the current distribution within each structure and consequently the magnetic field. As necessary, the actual structures and/or patient will be moved in conjunction with the changing current to allow the capsule to be moved throughout the body. This will also minimize the volume and strength of the magnetic field required to examine the patient. When there is no physical connection, power may be transferred to the capsule to recharge the power source through the use of the field generating structures. By holding the capsule stationary with some of the structures, the other structures may be used to rotate the

external magnetic field to operate a small generator within the capsule to recharge the power source. The fundamental motion of the generator may be rotary, curvilinear or linear. The medical practitioner, using visual feedback, will guide the capsule throughout the body part under examination. The magnetic field strength will be adjusted appropriately for direction change, curvilinear movement or special positioning for tissue biopsy/excision or other procedures. The programming of a predetermined movement pattern may be viable if an appropriate object (i.e. non medical) is being analyzed by the instrument.

The capsule will be able to measure the temperature, pH, substance concentration, pressure, strain, force, magnetic field, electric field and other physical quantities. The capsule will have the ability to detect and produce sound waves, to detect and produce electromagnetic waves (i.e. visible, infrared), to detect and produce elementary/nuclear particles and to examine by other modalities. The gyroscope/accelerometer will provide the ability to map in real time the positional progress of the capsule. A positional map will be created in real time of the entire procedure, areas of interest may be marked, and visual images or other data will be generated corresponding to each positional location of the capsule. The data may be analyzed in real time to produce a virtual three dimensional image of the completed portion of the exam. This will allow the doctor to quickly review the entire exam before removing the capsule. All of this data may be appropriately stored for future reference.

CLAIMS

I claim:

1. A magnetically responsive object or capsule whose movement is controlled by an external magnetic field. The moving capsule may or may not have a physical connection to other items. The external magnetic field is created by any number of magnetic field generating structures with the arbitrary positioning of each structure. The number and configuration of the structures will depend on the design parameters. The capsule will be moved by appropriately changing the current distribution within each structure and consequently the magnetic field. As necessary, the actual field generating structures and/or system being examined will be manually/autonomously moved in conjunction with the changing current to allow the capsule to be moved throughout the system under examination. For the purpose of a medical examination, the capsule will be referred to as magnetically propelled capsule endoscopy.

2. Referring to the instrument in claim 1, if the capsule does not physically connect to other items then the capsule may include the following:
magnets or magnetizable materials for movement and direction control; magnetic sensors; light sources; imaging lenses; transmitter and receiver for communication; magnetic pickup for power generation; gyroscope/accelerometer for location information; mechanical equipment for tissue biopsy/excision or other procedures; power source; electronics;

3. Referring to the instrument in claim 1, if the capsule is physically connected to other items then the capsule may include the following:
magnets or magnetizable materials for movement and direction control; magnetic sensors; light sources, imaging lenses, power lines, communication lines, injection hoses, suction hoses and other lines/hoses extending out the back of the capsule and connecting to the external control device; gyroscope/accelerometer for location information; mechanical equipment for tissue biopsy/excision or other procedures; power source; electronics.

4. Referring to the instrument in claim 1, magnetically propelled capsule endoscopy allows the gastrointestinal tract, reproductive tract, trachea/lungs, vascular system, or any body cavity to be viewed in real time from a wide range of angles.

5. Referring to the instrument in claim 1, magnetically propelled capsule endoscopy allows for tissue biopsy/excision from a wide range of angles.

6. Referring to the instrument in claim 1, magnetically propelled capsule endoscopy allows for a fast, comprehensive medical procedure with minimal anesthesia.

7. Referring to the instrument in claim 1 (version as described in claim 2), the instrument allows power to be transferred to the capsule to recharge the power source through the use of the field generating structures. By holding the capsule stationary with

some of the structures, the other structures may be used to rotate the external magnetic field to operate a small generator within the capsule to recharge the power source. The fundamental motion of the generator may be rotary, curvilinear or linear.

8. Referring to the instrument in claim 1, the instrument allows for real time display of information, virtual three dimensional image of the completed portion of the exam, real time mapping of the capsule's trajectory, marking of points of interest and storage of data.

9. Referring to the instrument in claim 1, the capsule allows the measurement of temperature, pH, substance concentration, pressure, strain, force, magnetic field, electric field and other physical quantities.

10. Referring to the instrument in claim 1, the capsule allows the detection and production of sound waves, the detection and production of electromagnetic waves, the detection and production of elementary/nuclear particles and the examination by other modalities.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US04/09471

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : A61B 1/00

US CL : 600/160, 117

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 600/160, 117, 109, 101, 118, 424, 300, 593

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,240,312 B1 (ALFANO et al) 29 May, 2001 (29.05.2001), see col.5, lines 16-20 and col.5, lines 48-65.	1-8, 10
A	US 2003/0060734 A1 (YOKOI et al) 27 March 2003 (27.03.2003).	1-10
X	US 2003/0023150 A1 (YOKOI et al) 30 January 2003 (30.01.2003), see paragraphs [0066], [0067], [0160], [0179].	1-4, 6, 8-10
A	US 2003/0020810 A1 (TAKIZAWA et al) 30 January 2003 (30.01.2003).	1-10
A	US 2002/0198439 A1 (MIZUNO) 26 December 2002 (26.12.2002).	1-10

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

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"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

20 July 2004 (20.07.2004)

Date of mailing of the international search report

27 AUG 2004

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